Optimal Operation and Management of Energy Storage Systems Based on Real time Predictive Modeling and Adaptive Battery Management Techniques

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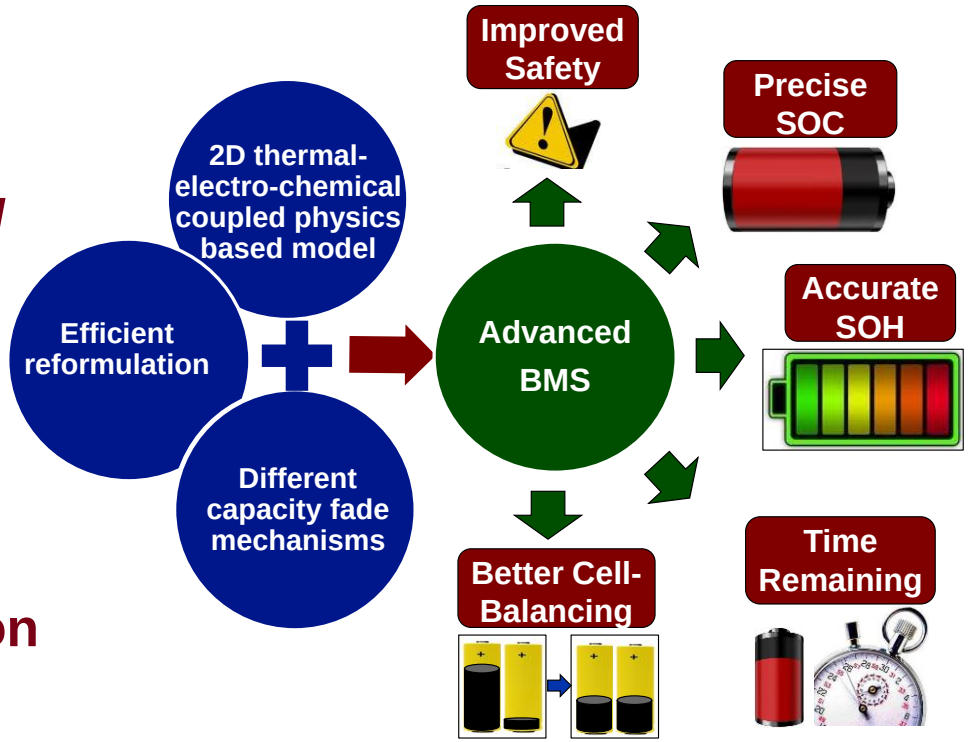
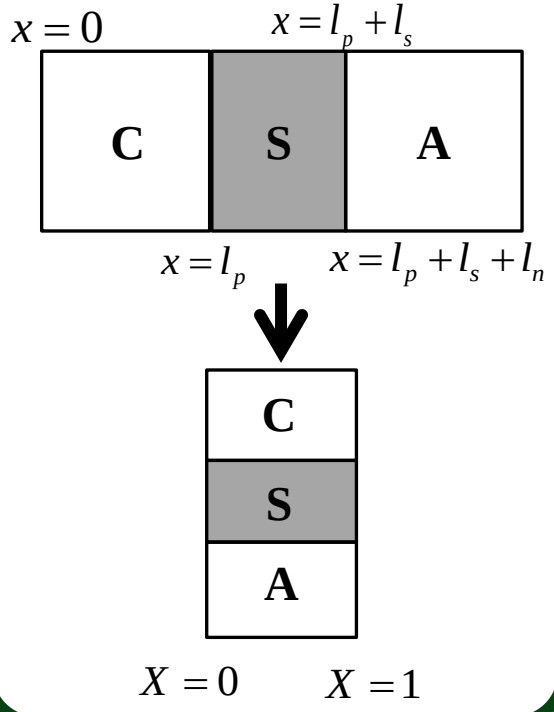
Technology

- **2D thermal-electrochemical coupled models with capacity fade mechanisms integrated into BMS**
- **BMS based on *fastest* and *detailed* physics based models**
- ***Pushing* the limit of simulation capability and model predictability**
- ***Pushing* the limit of state estimation efficiency and accuracy.**

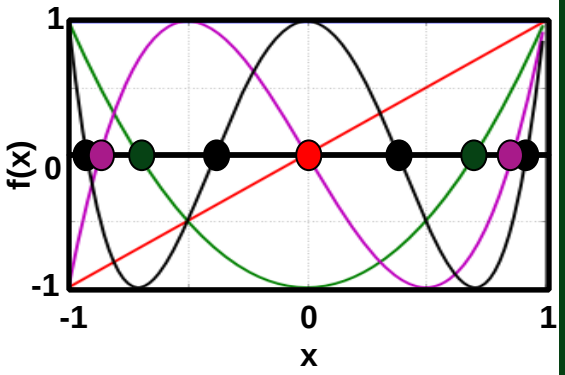


Mathematical Reformulation

Coordinate Transformation



Orthogonal Collocation



Analytical Solutions

Original System
3000-10000 DAEs

Reduces into

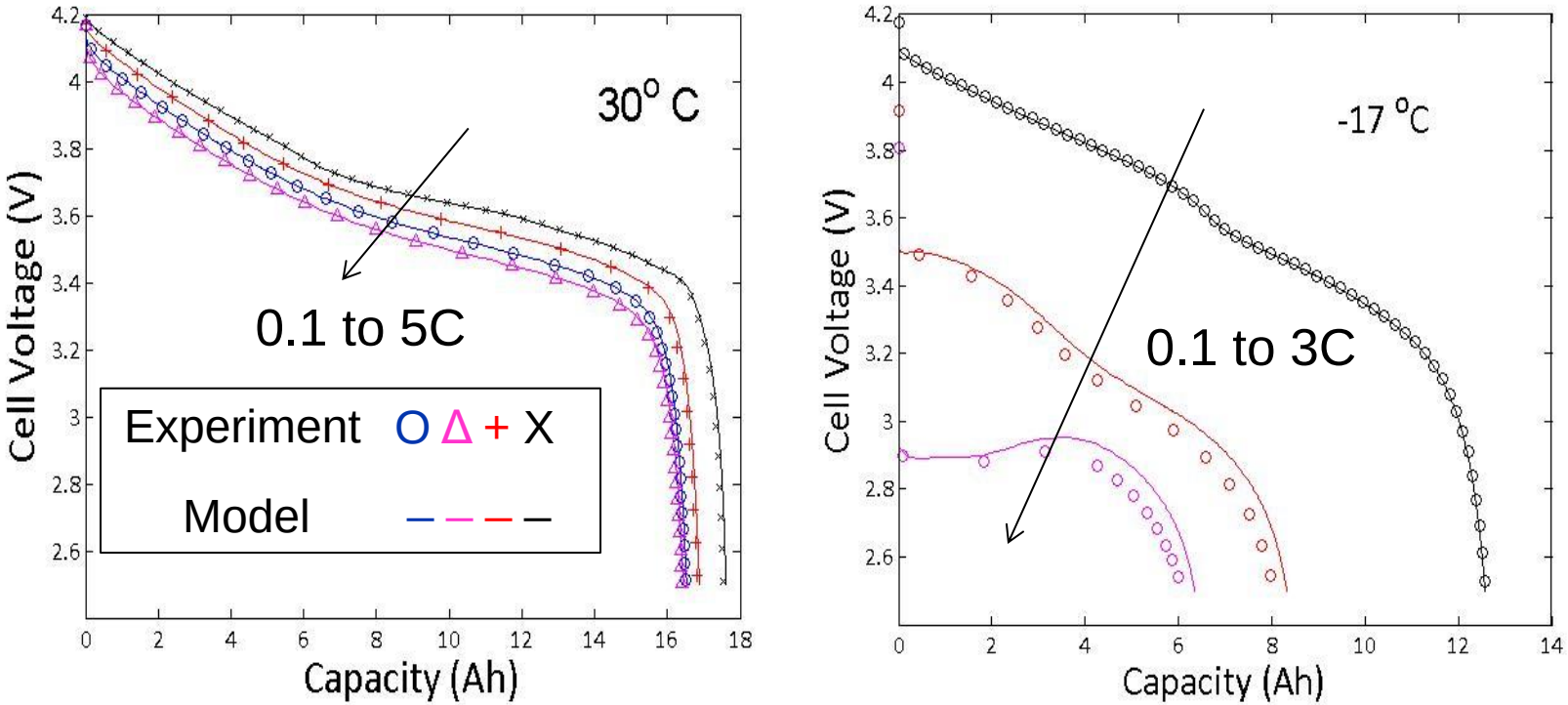
Final System
30-50 DAEs

[Northrop+, JES 2011]

Performance Targets and Validation Plan

- **Integration of microcontroller with physics-based control models onto a large format cell and to demonstrate**
  - **i) a 20% reduction in the weight of the cell**
  - **ii) a 50% reduction in the charging time for the cell without compromising the number of cycles**
- **3 cells will be subject to cycling with no heat control in a chamber held at -17, 0 and 30°C for 3 test plans. Life of cells tested in case (B) will be better than (A), and ideally closer to base conditions (Test-0)**
  - **Test 0: 30% to 85% SOC window**
  - **Test A: 15% to 100% SOC window**
  - **Test B: 15% to 100% SOC window with MPC based charging control**

Model validated at different temperatures



Model versus Experimental Data for NMC Chemistry

- **Electrochemical-Thermal models, calibrated for the NMC chemistry, have been tested for compatibility with NI and d-Space platforms and are now available**

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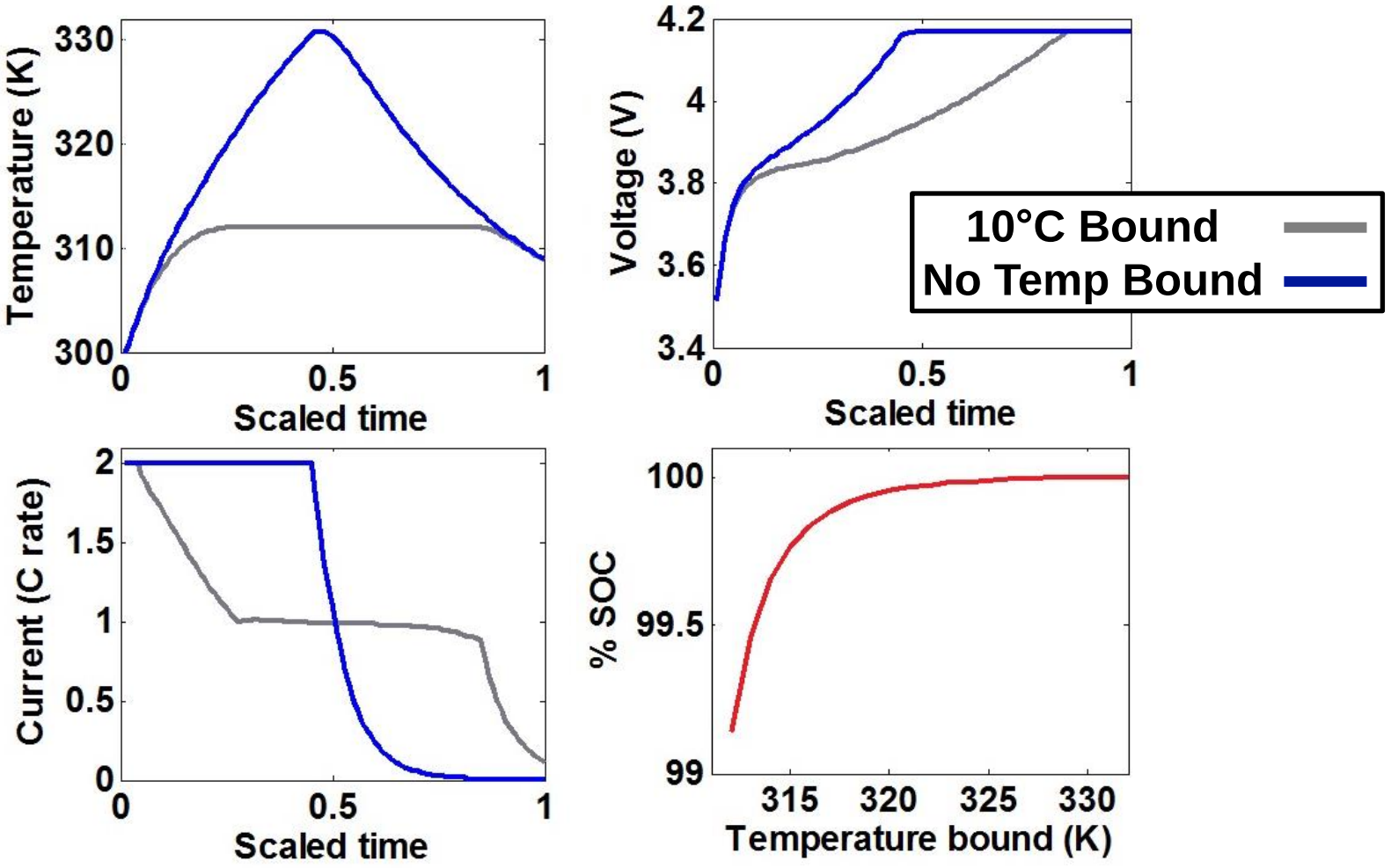
Optimal charging from model based control



Model based control will provide optimal charging protocols

[Suthar+, ACC, 2013]

Publications and Codes

- **Suthar, B., et al. "Optimal Charging Profiles for Mechanically Constrained Lithium-ion Batteries" *Phys. Chem. Chem. Phys*. 16(1), 277-287 (2014)**

- **De, S., et al. "Efficient Reformulation of Solid Phase Diffusion in Electrochemical-Mechanical Coupled Models for Lithium-Ion Batteries: Effect of Intercalation Induced Stresses" *J. Electrochem. Soc*., 160(10), A1675-A1683 (2013)**

- **Suthar, B., et al. "Optimal control and state estimation of lithium-ion batteries using reformulated models" *American Control Conference (ACC), 2013 IEEE*, (2013)**

- **Code for *optimally* charging batteries to minimize intercalation induced *stresses* is available at www.maple.eece.wustl.edu**